



LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

X-ray diffraction diagnostic design for the National Ignition Facility

M. F. Ahmed, J. Ayers, A. House, Z. Lamb, R.
Swift, D. Swift

August 28, 2013

SPIE Conference
San Diego, CA, United States
August 25, 2013 through August 29, 2013

Disclaimer

This document was prepared as an account of work sponsored by an agency of the United States government. Neither the United States government nor Lawrence Livermore National Security, LLC, nor any of their employees makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States government or Lawrence Livermore National Security, LLC. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States government or Lawrence Livermore National Security, LLC, and shall not be used for advertising or product endorsement purposes.



X-ray diffraction diagnostic design for the National Ignition Facility

**Presented
August, 2013
Paper 8850-22**

Maryum F. Ahmed, Jay Ayers, Allen House,
Zachary S. Lamb, Ray Smith, David W. Swift

Lawrence Livermore National Laboratory

Lawrence Livermore National Laboratory • National Ignition Facility & Photon Science

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344

National Ignition Facility (NIF)



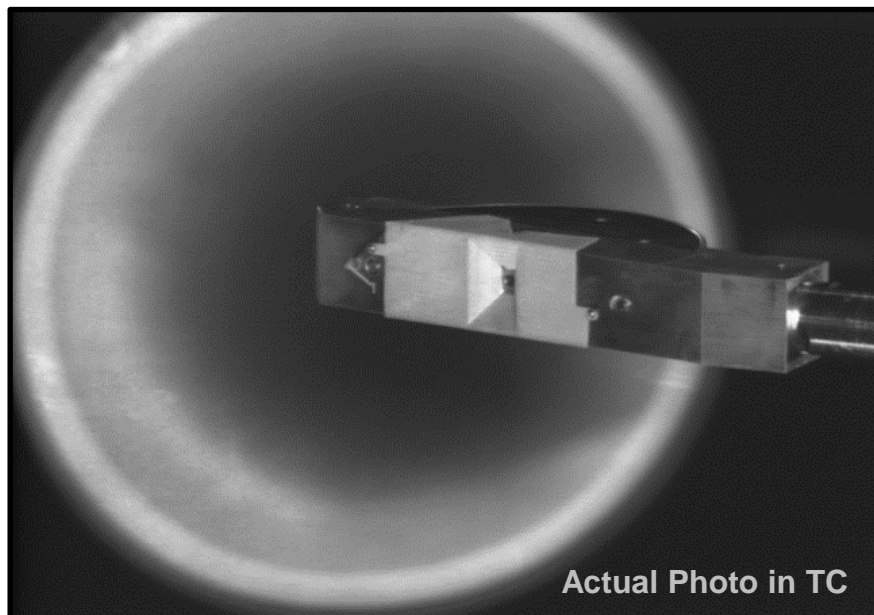
National Ignition Facility



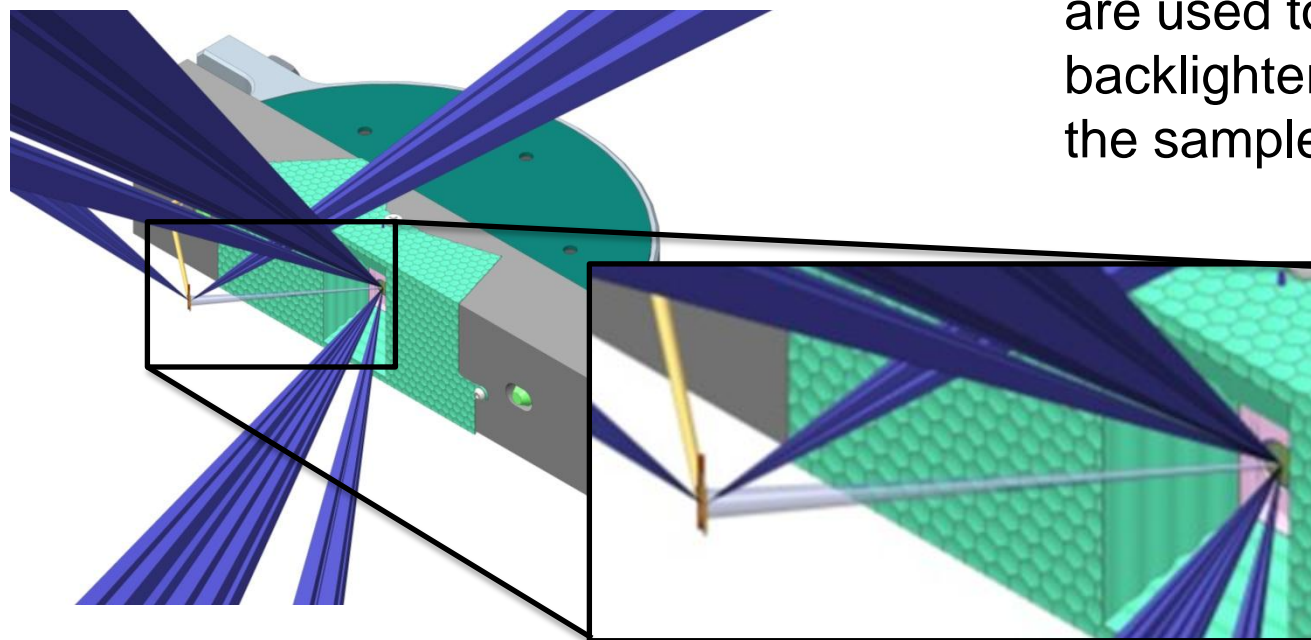
Laser Bay 2

- NIF is located at Lawrence Livermore National Laboratory in Livermore, CA.
- Highest energy laser ever constructed.
- Facility includes 192 lasers, each of which is the world's most powerful laser.
- Has been used to compress tantalum to over 10 Mbar and diamond to 50 Mbar, recreating the most extreme planetary conditions.

What is the TARget Diffraction In-situ Diagnostic?



- TARDIS allows for in-situ characterization of highly compressed crystal structures.
- Up to 6 laser quads are directed at the TARDIS crystal sample, to ramp compress the sample up to 30 Mbar.
- Up to 4 additional laser quads are used to illuminate a backlighter source foil, probing the sample with He- α keV x-rays.



What does the TARDIS instrument look like?

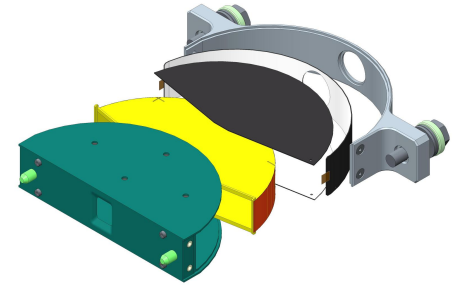
Target and diagnostic on a single platform to capture crystal diffraction lines.

Standoffs

- Controls diagnostic assembly's seated depth

Diagnostic Assembly

- Holds filters and image plates
- Seats inside a pocket on the target assembly



Spring loaded fasteners

- Secures the two bodies together
- Spring washers allow for compliance at time of impact.

Target Assembly

- Holds crystal sample
- Provides mounting arm for entire TARDIS assembly

Alignment pins

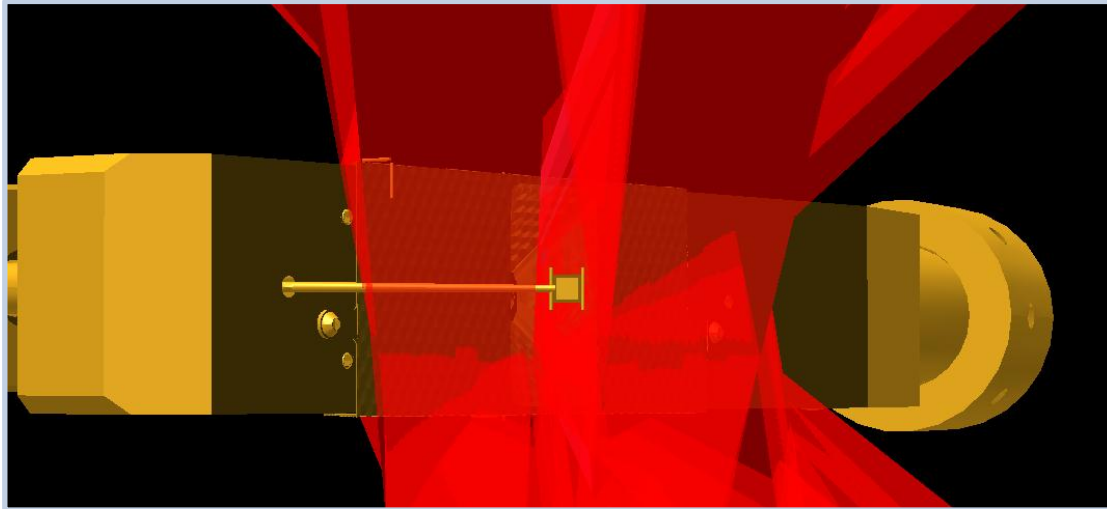
- Control diagnostic assembly's horizontal and vertical position

Mounting ARM
(Not Shown)

Section View

How was the debris mitigation addressed?

Unconverted 1ω and 2ω laser light has the potential to create debris which poses a risk to TARDIS and other systems in the NIF target chamber.



Simulation of TARDIS bathed in unconverted laser light.

- Analysis was performed using LASNEX, laser fusion simulation software
- Used to determine shielding requirements
- Loading results used for finite element analysis of TARDIS structural components.
- Radiation-hydrodynamic simulations were used to predict the mass and trajectory of resulting debris, predicting minimal potential for damage and loss of data.

What does the diagnostic assembly include?

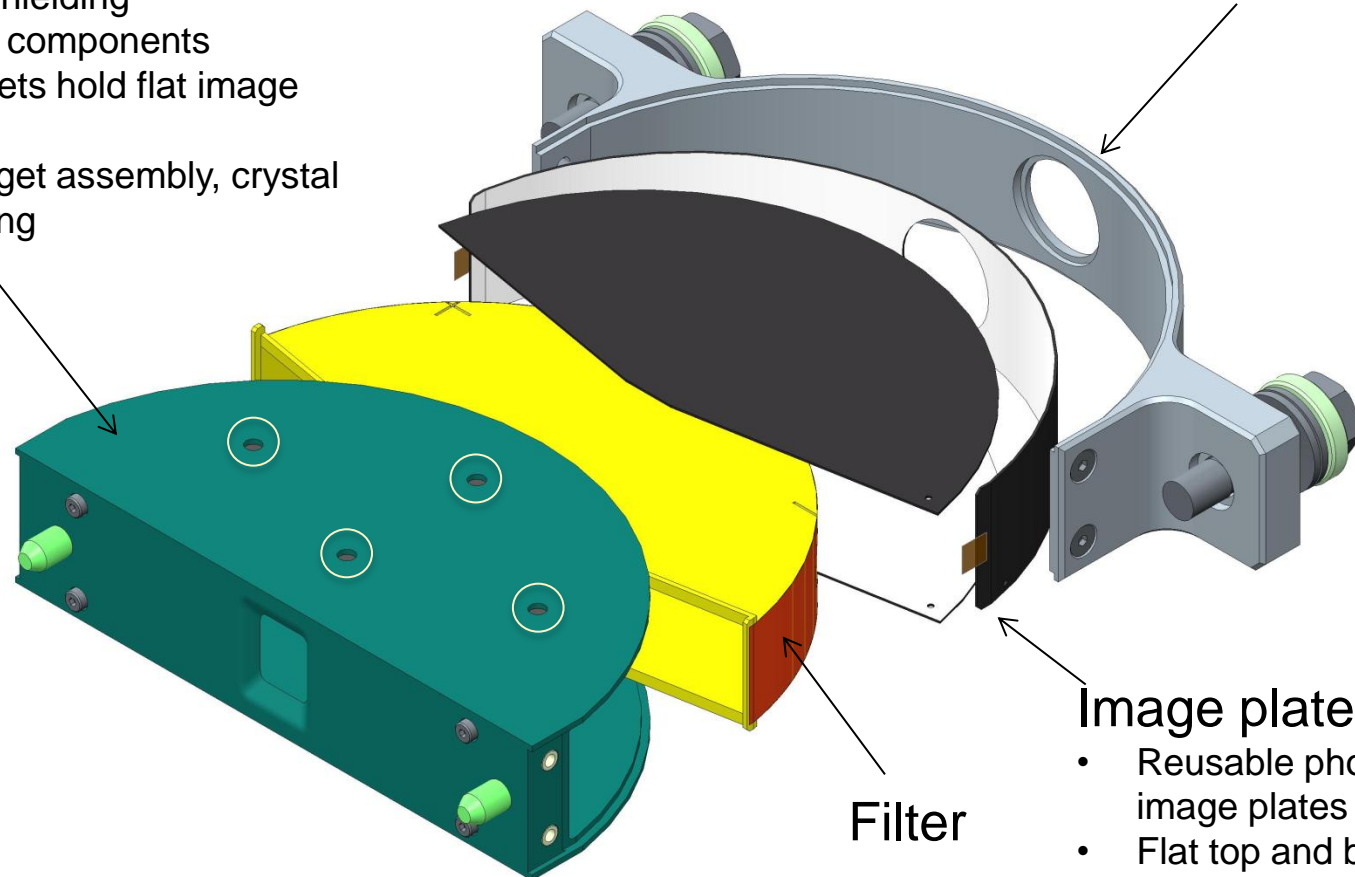
Primary function to house imaging components.

Tungsten body

- Provides high Z shielding
- Holds positioning components
- Embedded magnets hold flat image plates in place
- When fixed to target assembly, crystal sits in front opening

Back plate

- Holds curved image plate in place
- Contains aperture for viewing by VISAR diagnostic



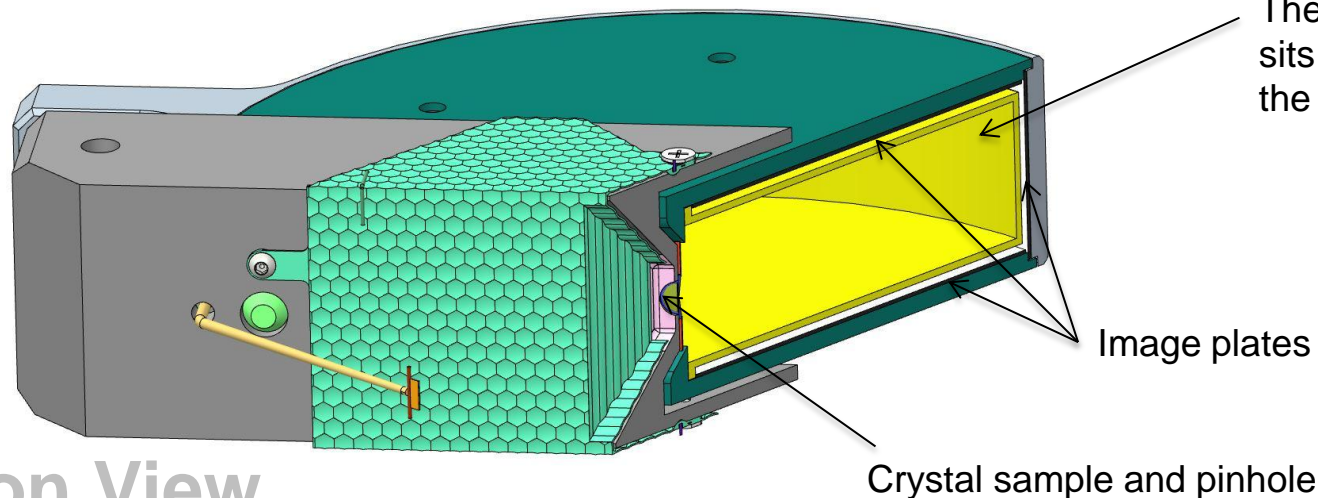
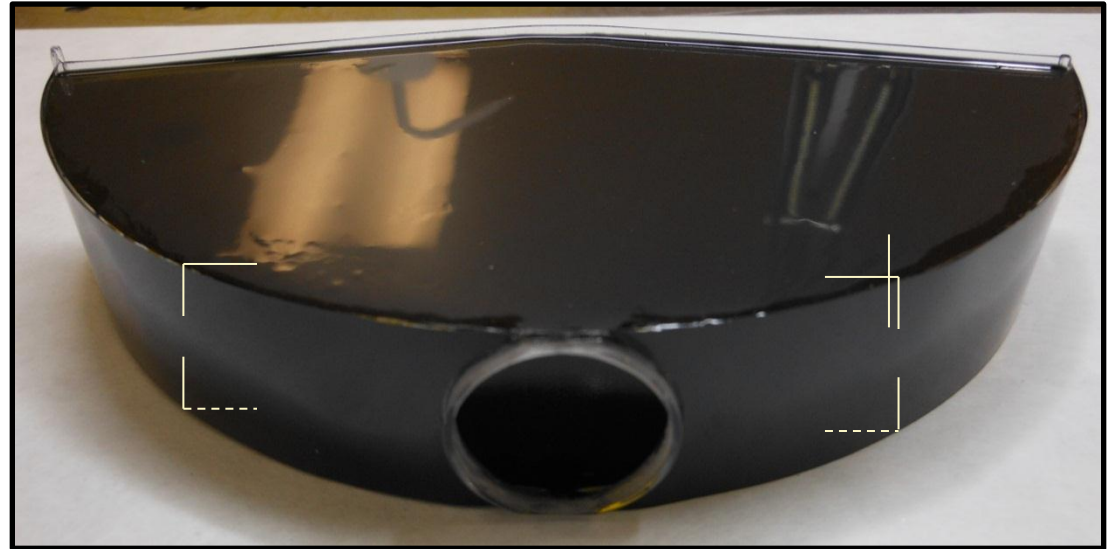
Filter

Image plates

- Reusable phosphor screen image plates
- Flat top and bottom plates
- Curved back plate with VISAR aperture

Filter material matched to back lighter source

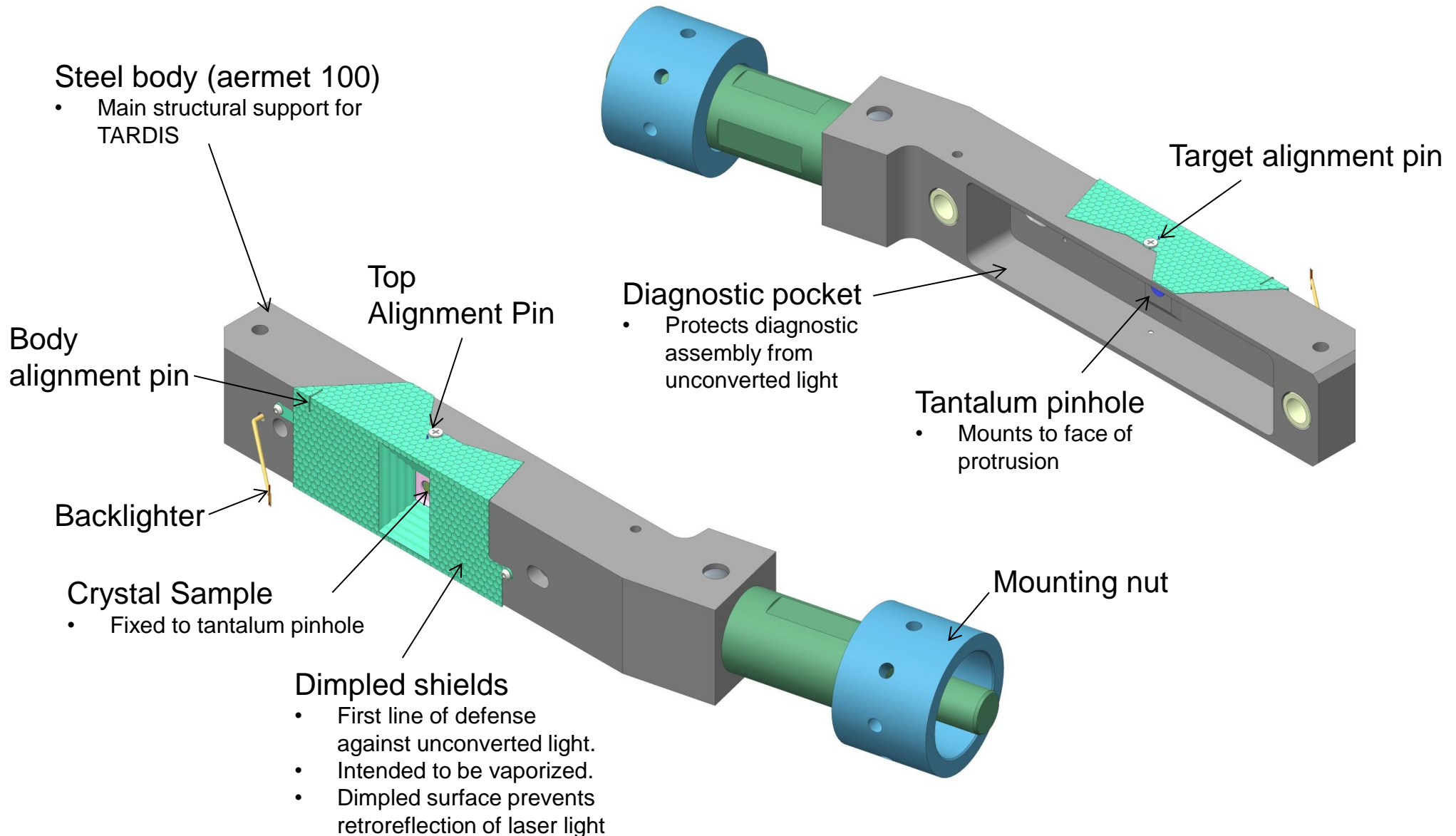
- Built on rapid prototype polycarbonate base.
- Contains VISAR aperture.
- Wire fiducials fixed inside grooves built into the base.
- Polyimide sheets, coated in filter material (Ge, Zr, Zn, Cu) are fixed to external surfaces of base.
- Final layer of black polyimide sheet placed over filter material
- Clear edges coated with opaque graphite coating.



Section View

What is included as part of the target assembly?

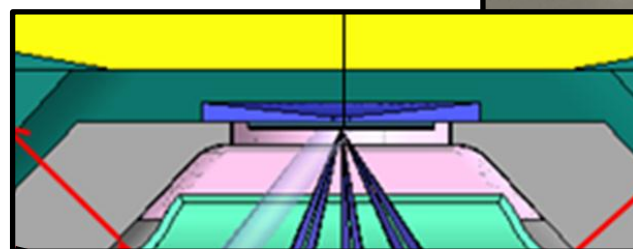
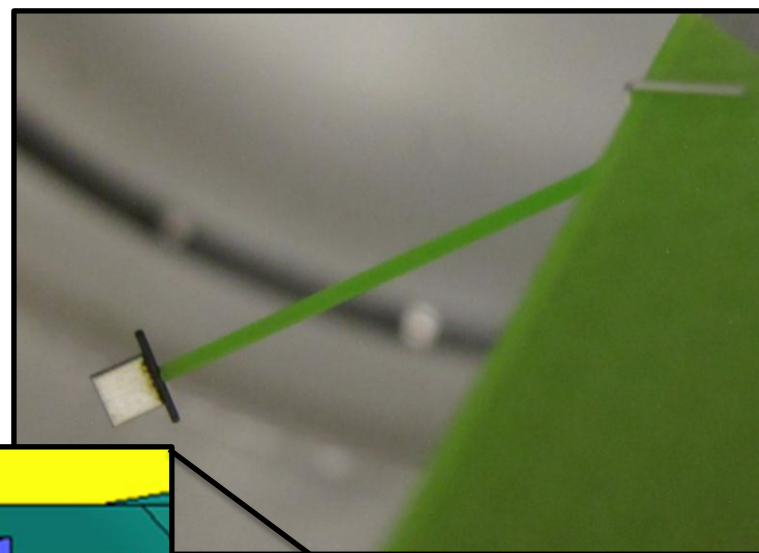
Primary function to house crystal sample.



Back lighter and tapered entrance aperture

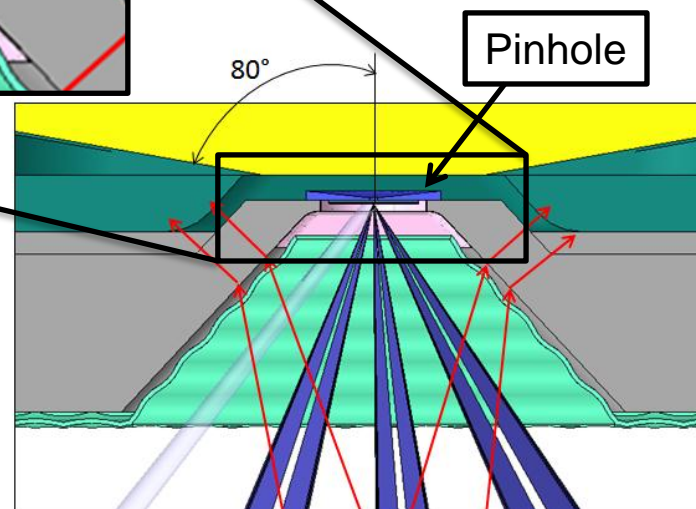
Backlighter

- Thin foil material impinged upon by laser beams.
- Experiment specific material, coated to thin substrate of graphite or polyimide.
- Creates quasi-monochromatic He- α x-ray source at time of maximum compression.
- Supported by rapid prototype polyimide stalk.



Tapered Opening

- Allows 3 ω laser light and x-rays to reach crystal sample.
- Designed to provide adequate shielding of converted 1 ω and 2 ω laser light
- Pressure wave travels normal to the surface
- Pinhole is positioned to provide $\pm 80^\circ$ data collection angle.



Red arrows represent direction of unconverted laser light and corresponding pressure wave.

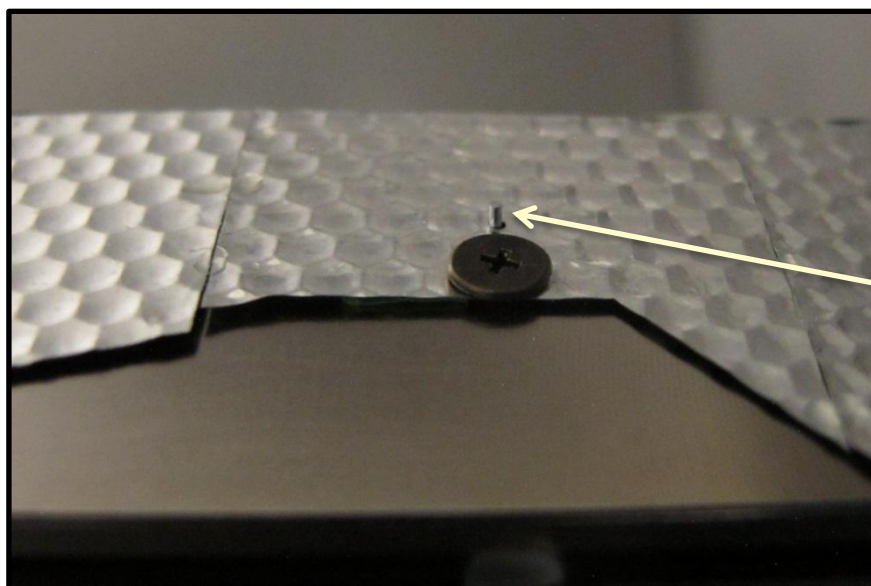
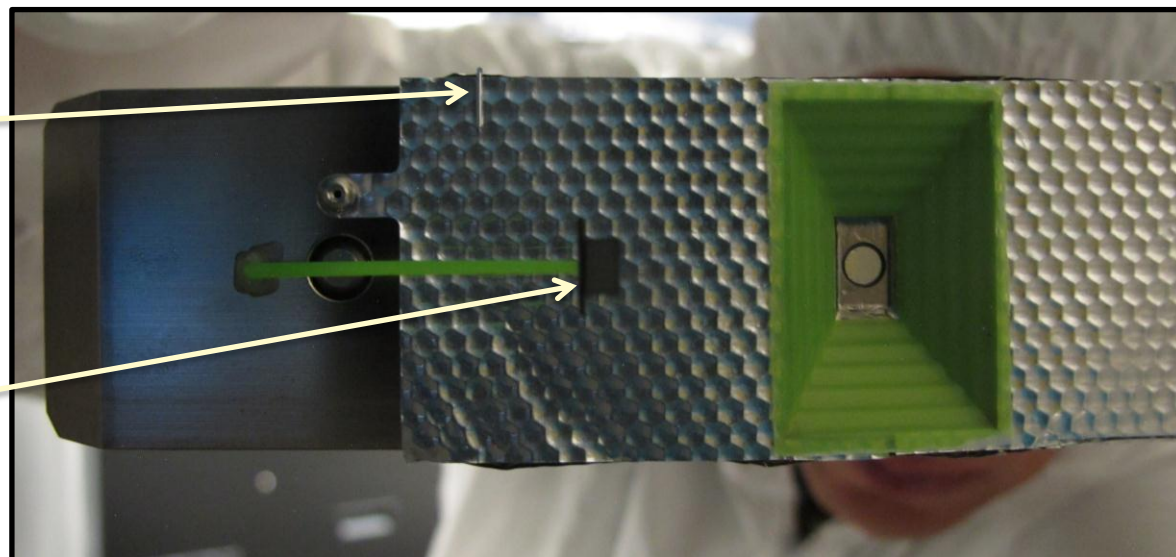
TARDIS Alignment Features

Body Alignment Fiducial

- Used for gross positioning

Backlighter Fiducial

- Used for laser pointing



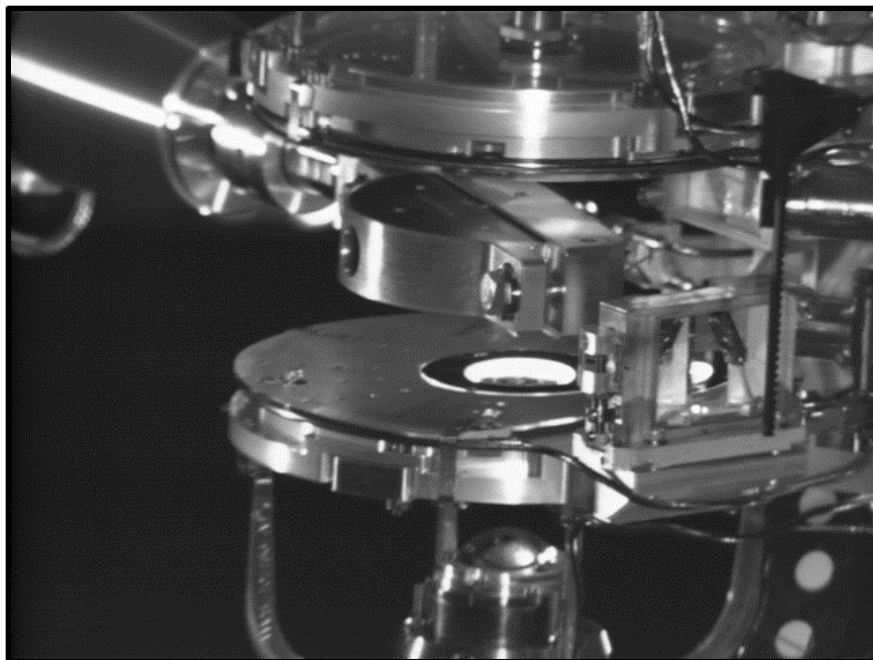
Target Alignment Pin

- Positioned directly above and below sample's front surface.
- Errors in fiber and target position are measured and known.
- Used to fine tune position of crystal sample and laser pointing.

Positioning and Alignment in Target Chamber



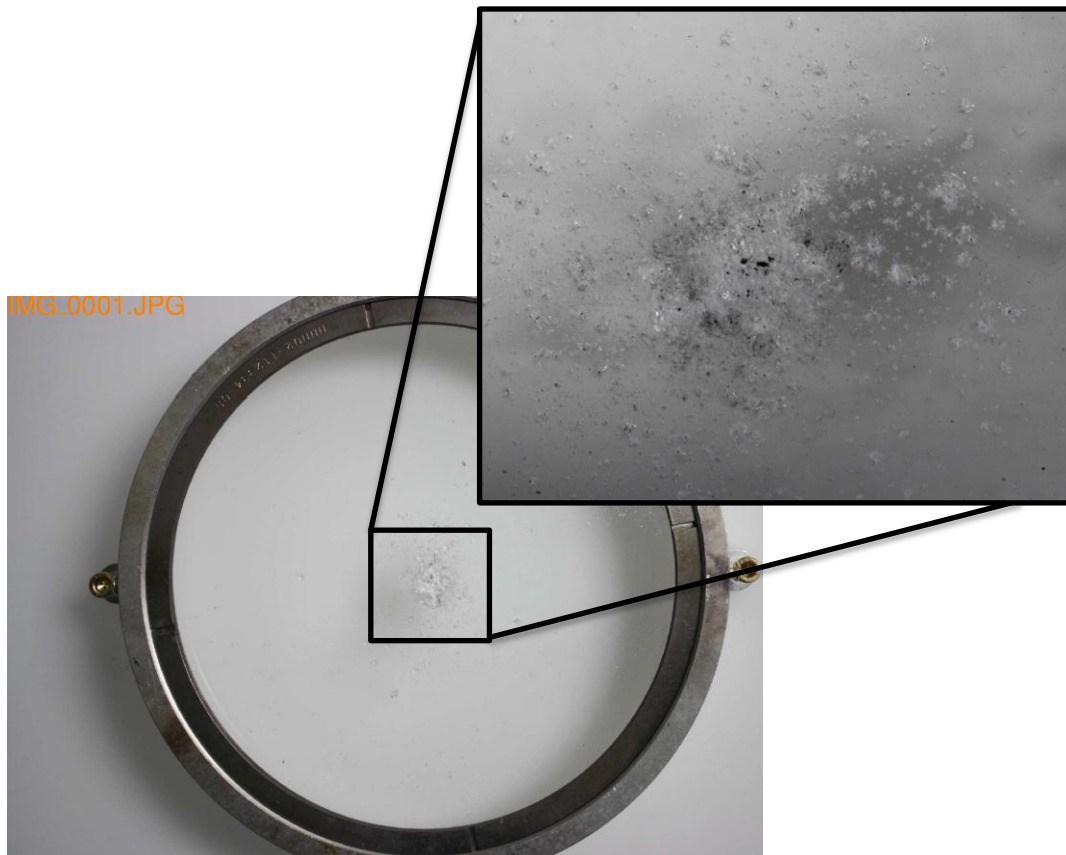
- TARDIS is supported and inserted into the target chamber by the Target Positioner (TARPOS), via the arm extension and mounting nut.
- TARDIS transfers much higher loads to TARPOS than any previous experiment.
- TARPOS connections were analyzed and strengthened to withstand the higher loads.



- TARDIS is inserted into the Target Alignment Sensor (TAS), in the NIF target chamber.
- TAS uses the 4 alignment fiducials for positioning TARDIS and aim beams at the crystal and backlighter.

TARDIS Status August 2013

- The first two TARDIS shots have been successfully deployed and all shot goals have been met
- Unconverted light shields were vaporized and agreed with simulations performed
- VISAR debris shield worked as anticipated and collect target debris

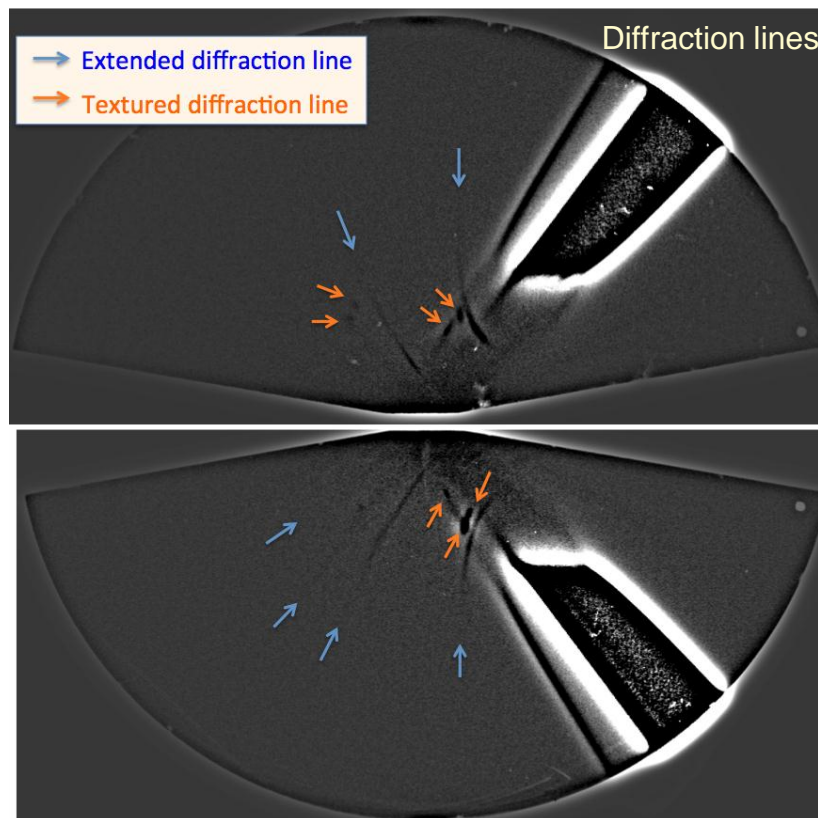


Sample TARDIS Data

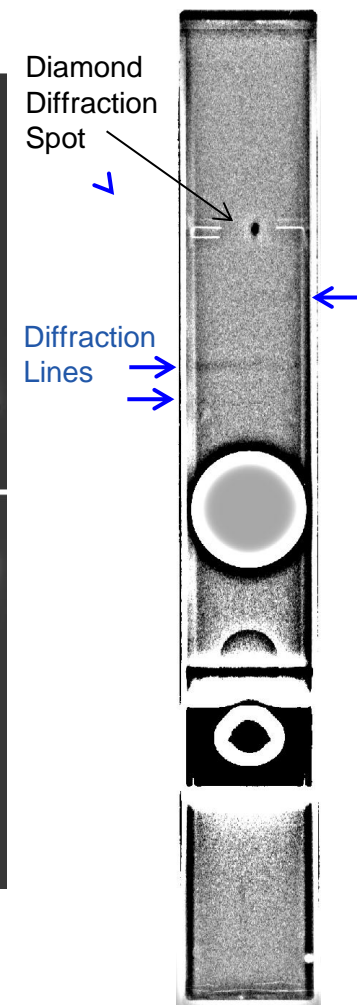
Primary objectives

- 1) Measure x-ray diffraction from a driven Ta target. ✓
- 2) Evaluate performance of backlighter with phase plates on all beams. ✓
- 3) Ensure damage incurred on x-ray diffraction box is within expected levels. ✓

TARDIS: Upper/Lower Image plates

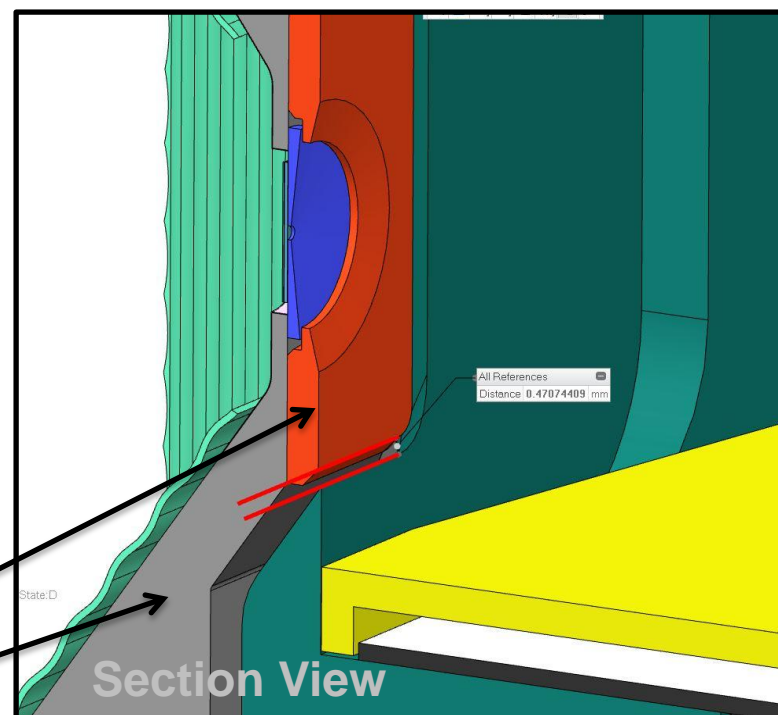
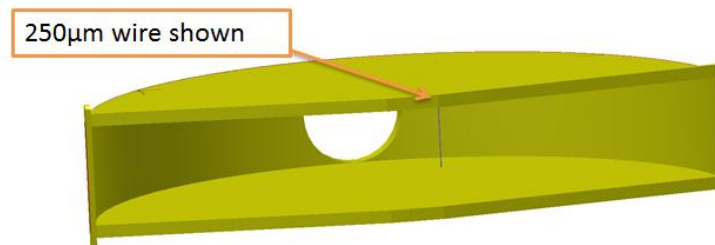
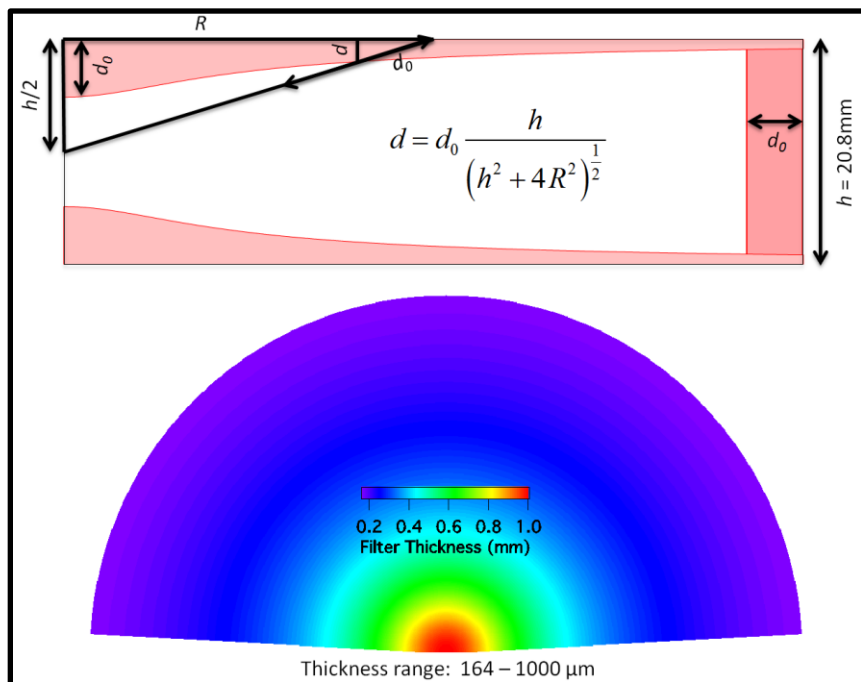


TARDIS: Curved plate



After review of the first 2 shots what changes are needed?

- What are the desired changes to TARDIS after review of data
- Additional Ta or W wire to identify the source of fluorescence (noise)
- Graded filter coatings and polycarbonate filter housing, or possible hemispherical filter design
- Additional shielding to reduce background signal



Proposed 1mm thick Ta patch
Aermet Target Body

Conclusion

The first 2 NIF shots have met all shot goals

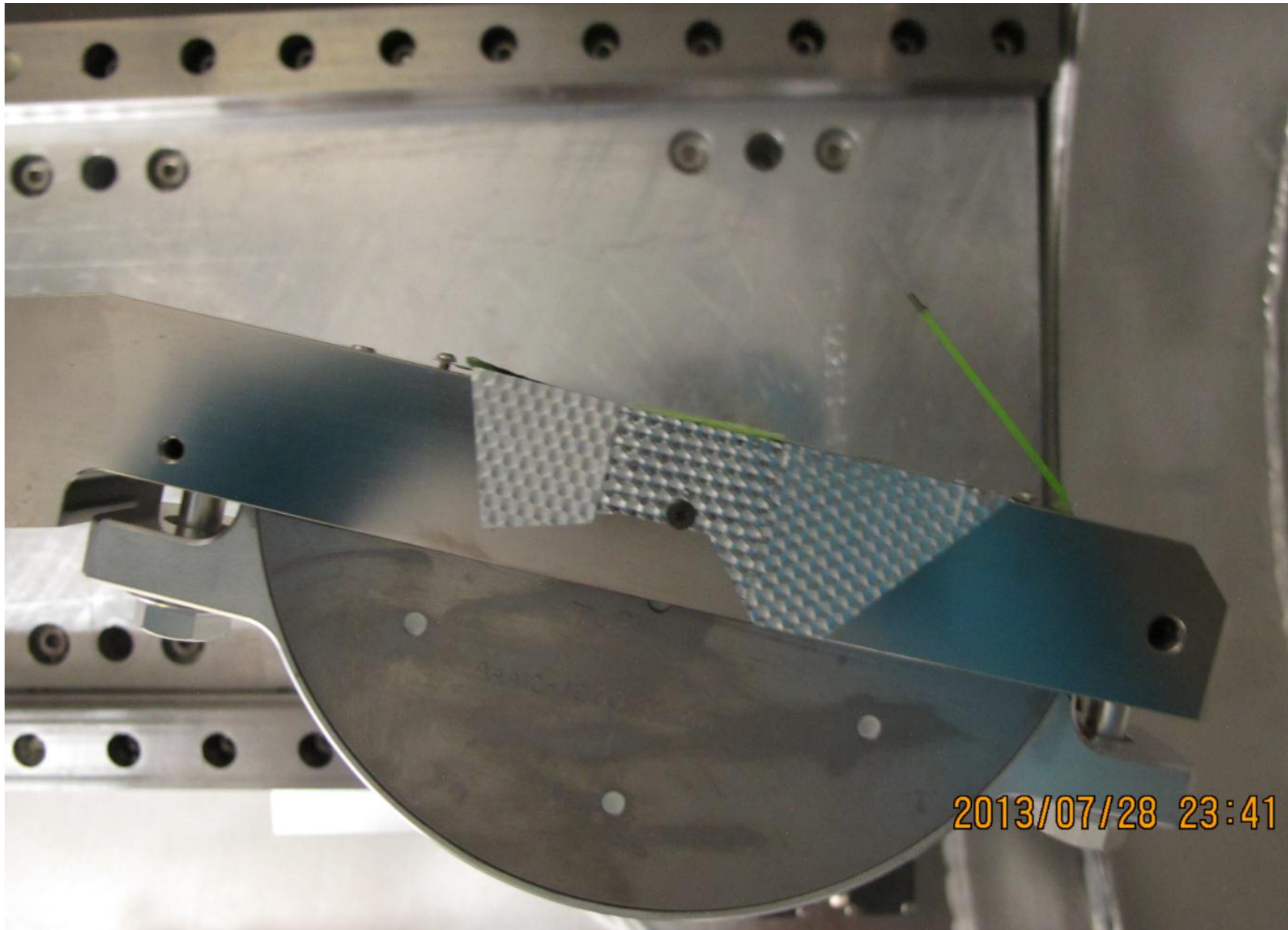
- Measured x-ray diffraction from a compressed crystal sample.
- Ensured damage incurred on TARDIS is within expected levels.
- Collected good data from VISAR and other diagnostics.

Changes needed for FY14

- Improved filter design to attain uniform filtering on top and bottom image plates. Design concepts include graduated top and bottom, or possibly a hemispherical filter.
- Additional shielding to increase background suppression.

Using the NIF, we can compress our samples to high pressures and low temperatures thereby keeping the material in the solid state at extreme levels of compressions found within the cores of giant planets (~ 10 's of Mbar). The TARDIS x-ray diffraction diagnostic will allow researchers to quantify the change in crystal structure as a function of applied pressure which is expected to have profound impact on our understanding of planetary evolution.

Questions ?



NIF

